Preliminary Studies on the Cultivation of American Sumac as a Source of Tannin

By

A. F. SIEVERS and I. D. CLARKE

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Introduction

Sumac has been extensively used as a tanning and dyeing agent since ancient times. A large proportion of that used in recent times and the material of highest quality has been produced in Sicily, where it is grown as a cultivated crop. Cultivation on a commercial scale in other locations apparently has never been achieved, although consideration has been given to the matter at various times.

After the first World War, considerable interest was manifested in domestic sources of tannin, especially by the Central European countries, and sumac cultivation was one possible source under investigation. In 1937, Belavsky and Slama[3] reported on work at an experimental plantation started in 1933 by the Bata Co. in Czechoslovakia in which 26,000 plants of *Rhus cotinus* L. and 9,000 plants of *Rhus typhina* L. were growing. The latter species was referred to as American sumac. They found that the leaves of one and two-year old plants were low in tannin. The tannin content was higher the third year and rose throughout the summer, reaching a maximum in red leaves in the fall. Giglioli[6] has reported 25 per cent tannin in *Rhus coriaria* L. plants growing in South Africa. He states that the original plants were imported from Sicily but gives no further information regarding them. The present status of these or other plantings that may have been made, of course, cannot be determined under present conditions.

In the United States black or dwarf sumac (*Rhus copallina* L.), white or smooth sumac (*Rhus glabra* L.) and staghorn sumac (*Rhus typhina*) have long been commercial sources of tannin and collection of the leaves of these species and their sale to tannin extract manufacturers has been a small, sporadic industry for many years, mainly in Virginia. The desirability or even the possible necessity for cultivating sumac in the United States was mentioned from time to time by various writers[1,2,7], but until recently no plantings apparently were ever made with the object of developing sumac as a cultivated crop for production of tannin.

In 1940, the important role of tanning materials in the national welfare,

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especially during time of war, was pointed out by Frey and Sievers[5]. They emphasized the need for a study of the basic requirements for the cultivation of suitable materials as crops and mentioned sumac as one of the materials on which work had already been started. Sumac appeared to be worthy of consideration because, while it is suitable only for certain types of light leather, if increased quantities of good quality material were available in this country it would doubtless find considerable use as a replacement for Italian sumac and certain other tannins that are now imported.

Not only may sumac serve a useful purpose in increasing the available supply of tannin, but it may be of value in other directions as well. During the last depression, when an effort was being made to reduce the acreage of surplus products, a search was made for new crops suitable for marginal lands. Sumacs appeared promising in this program because several varieties have shallow, spreading root systems and so might serve both to prevent erosion and to provide a crop on land that was unsuitable for intensive cultivation. Sumac is often one of the first plants to come back naturally in badly eroded locations.

Before such a development can be initiated, Frey and Sievers[5] point out that much fundamental data on cultural, economic, geographic, climatic, and agricultural conditions are needed. They state that studies to evaluate some of these factors were under way and that sumac plants for this purpose were being grown at Arlington Experiment Farm, Arlington, Virginia. It is the purpose of this paper to present a complete report on this Arlington planting.

Because of the cost of labor, sumac probably can never become an established crop in the United States and compete with imported sumac unless much of the harvesting and handling can be done by machinery. It is believed that mowing machines adapted to this purpose either are available or can readily be designed and built, but mowing can only be adopted if it is not damaging to the plant and if abundant new growth having a satisfactory tannin content will develop from the stumps. Reliable information concerning these points must be obtained before rational practices can be determined. This paper records the results of experiments on the propagation of three species of sumac from seed and rootstock, and the effect of various harvesting procedures on the quality and quantity of material thus obtained and on subsequent growth.

At this point it may be well to emphasize the fact that machine harvesting will make necessary some process for the mechanical separation of stems from the leaves. In Sicily, the farmer flails the dry sumac and removes and discards much of the stem material. The factories that grind sumac further purify it by "ventilation," a process of fanning or air separation. A product of high quality is thus obtained.

In the United States sumac is usually only dried and then marketed as gathered. Even a little hand or machine mowed material has been marketed occasionally, but since it was subjected to no refining process it only contributed further to the poor reputation of American sumac. The growing of sumac

in this country cannot become a stable industry unless a product of better quality is produced than has been marketed heretofore. Improvement in quality both by selection of breeding stock and by better methods of handling should be possible and is being studied.

Plan of the Experiments

Sumac may be propagated by seed or root cuttings. It has not been determined which of these methods is the more practical, commercially. Therefore, the experiments were planned so that they would furnish data on the effects of time of harvesting within and between seasons on the yield and tannin content of the harvested material from the three species of American sumac mentioned, grown from seed, and from root cuttings on several types of soil.

The experiments were conducted at Arlington Experiment Farm, Arlington, Virginia. The first plantings were made in the spring of 1938, using root cuttings of *R. copallina*, *R. glabra*, and *R. typhina* on heavy loam in a section of the farm flats known as Section W, and root cuttings of the first two* and seed of all three on clay loam in the upland section of the farm known as Section F. The root cuttings were in all cases planted in rows 133 feet long and 3.3 feet apart, but only sufficient seed was available to plant respectively 55, 38, and 35 feet of row of the three species. The roots of *R. copallina* were obtained near Wicomico, Maryland, those of *R. glabra* at Great Falls and near Alexandria, Virginia, and those of *R. typhina* at Great Falls, Virginia. The seed of all three species was collected at various places in nearby Virginia. The following year seed of the three species from several sources was planted on gravelly loam in Section E, in rows 133 feet long and 3.3 feet apart. The relative growth of the plants of the three species from root cuttings and seed by late summer is shown in Figs. I and II.

Sumac seed usually germinates slowly and unevenly. To overcome this partly, the seed was treated for 30 minutes with concentrated sulfuric acid and then thoroughly washed to remove all traces of the acid and dried. It was planted in well prepared soil and covered lightly.

The roots were cut into pieces about 12 inches long and planted by laying the pieces nearly end to end in trenches about 4 inches deep, covering with soil and tamping the latter firmly. The *R. copallina* roots ranged from about one-third to two-thirds of an inch in diameter while those of the other two species were of somewhat greater diameter. The number of rows planted in 1938, the number of feet of row harvested on various dates, and the kind of samples collected for analysis are shown in Tables I and II. The 1939 seed plantings made on gravelly loam in Section E, consisted of 36 rows 133 feet long, planted with seed from the three species as follows: (1) *R. copallina*, rows 1–6 with seed from Halifax, Va., rows 7–12 with seed from Rockingham,

*One plant of *R. typhina* was grown from rootstock in Section F, it is shown in Fig. 2.

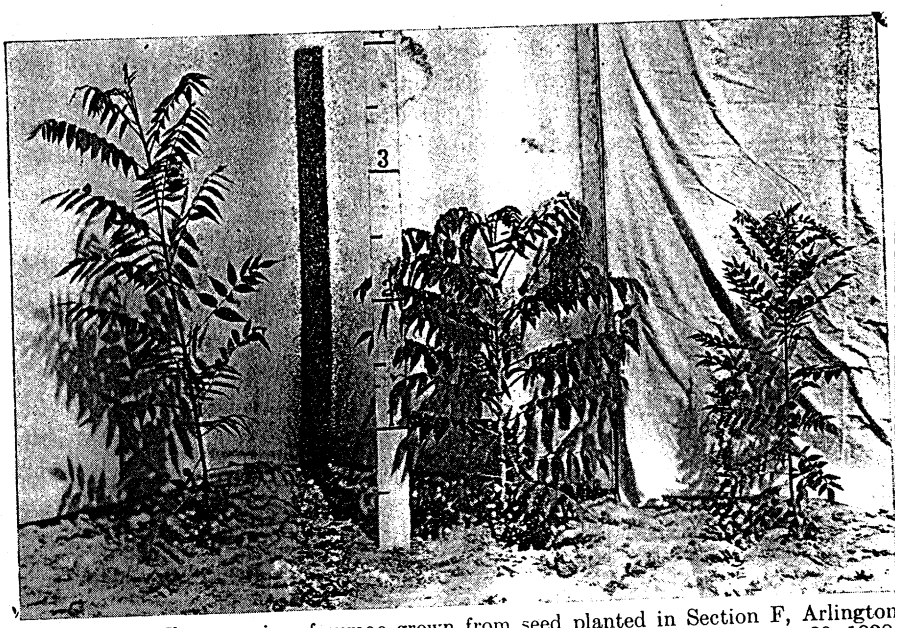

FIGURE I. Three species of sumac grown from seed planted in Section F, Arlington Experiment Farm, Arlington, Virginia, on May 11, 1938. Photographed August 29, 1938. Left, *Rhus typhina*, center *R. glabra*, right *R. copallina*.

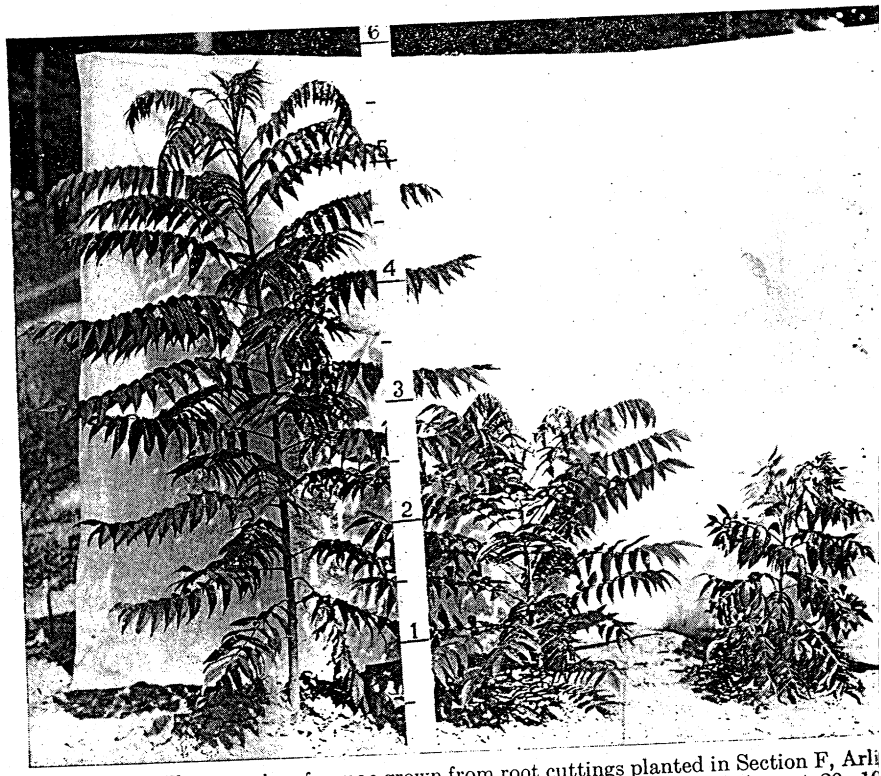

FIGURE II. Three species of sumac grown from root cuttings planted in Section F, Arlington Experiment Farm, Arlington, Virginia, April 1938. Photographed August 29, 19 Left, *Rhus typhina*, center, *R. glabra*, right *R. copallina*.

N. C.; (2) *R. glabra,* rows 13–16 with seed from Winston Salem, N. C., rows 17–20 with seed from Athens, Ga., rows 21–24 with seed from Macon, Ga.; (3) *R. typhina,* rows 25-36 with mixed seed from several localities in western Maryland. These plantings, therefore, also afforded opportunity to compare the tannin content of a species grown from seed from widely separated localities.

Sampling and Harvesting

The samples for analysis were obtained as often as deemed necessary and in such a way that the results would be unaffected so far as possible by individual plant variation or differences in soil. Several leaves were picked from the middle portion of each plant when a row or part of a row was sampled. In the case of the larger plantings of seedlings random samples were obtained by collecting leaves from many plants throughout the plot but not necessarily from all plants. The samples were carefully dried indoors and stored for analysis.

Large quantities of material cut in connection with the harvesting experiments were spread thinly on a wooden floor in an airy building until dry enough to bag. When necessary, portions of such lots were separated into leaves and stems to determine the proportion of these present and the separated parts further prepared for analysis. Data were thus obtained which make it possible to determine the yield of leaves and stems and calculate the yield of tannin from unit areas under various conditions and procedures.

Method of Analysis

The leaves were prepared for analysis by grinding in a Wiley mill to pass a 2 mm. sieve. The quantity necessary to give a concentration of 4 grams of tannin per liter was weighed out, soaked for an hour in water at room temperature, then transferred to a Frey-Reed type of glass extractor[4] and extracted to two liters in 7 hours. The solution thus obtained was analyzed for tannin by the Official hide powder method of the American Leather Chemists Association.

Discussion of Comparative Results with Three Species Grown from Seed and Root Cuttings

The details of the experiments and the procedures followed resulted in voluminous data which furnish the basis for numerous comparisons concerning yields, quality, effects on the life of the plants, etc. These data are assembled in a number of principal tables. Those obtained in connection with the plantings of seed and root cuttings made in 1938 are presented in Tables I to IV, and all pertaining to the seedlings started in 1939 are included in Tables V to IX.

TABLE I. Effect of age of plant, cutting history and date of sampling on yield of three species of sumac grown from seed or root cuttings on two soil types in Sections F and W at Arlington Experiment Farm, Arlington, Virginia, in 1938-1940

Species of Rhus and Sample No.	Grown from	Section and Row	Portion of Row	Age of Plants	Cutting History[1]	Cutting for Season[2]	Date of Sampling	Length of Row Cut or Sampled[3]	Stems per Foot of Row	Length of Stems	Proportion of Leaf on Moisture-Free Basis	Tannin in Leaves	Calculated per Acre Yield of Moisture-Free		
													Leaves	Stems	Leaf Tannin
				season				feet	avg.	in.	%	%	lbs.	lbs.	lbs.
R. copallina															
1	Seed.....	F1	AB	First	....	First	8-24-38	18	4.9	....	74	13.7	1204	419	165
2		"	C	"	....	"	10-18-38	9	6.1	28	64	15.0	1976	1128	296
3		"	A	"	a	Second	"	9	7.0	5	..	14.3	169	39[4]	24
4		"	DEF	Second	....	Random	7-26-39	28	....	....	..	17.9	....	....	....
5		"	C	"	b	"	"	9	....	....	..	17.6	....	....	....
6		"	B	"	a	First	"	9	10.0	12-51	67	18.3	3598	1787	658
7		"	A	"	ab	"	"	9	5.3	"	69	18.2	2662	1209	484
8		"	DEF	"	....	Random	9-25-39	28	5.3	28-95	41	15.3	7706	10925	1178
9		"	C	"	b	First	"	9	10.2	12-66	55	16.7	6285	5154	1050
10		"	B	"	ac	Second	"	9	10.7	2-9	76	14.9	1173	380	175
11		"	A	"	abc	"	"	9	8.3	8-24	77	15.9	1037	302	165
12		"	D	Third	d	First	7-16-40	8	....	40	56	20.8	5568	4398	1158
13		"	A	"	abcd	"	"	10	....	"	74	21.3	1307	450	278
14		"	E	"	d	"	9-27-40	10	....	24-56	51	19.2	4760	4591	914
15		"	D	"	de	Second	"	8	....	12-34	70	19.8	1502	652	297
16		"	A	"	abcde	"	"	10	....	8-34	74	17.4	691	249	120
17	Root cuttings.....	F2	A	First	....	First	8-24-38	13	1.0	....	84	25.2	639	124	161
18		"	B	"	....	"	10-18-38	16	0.5	24	75	27.2	1913	649	520
19		"	C	"	....	Random	7-26-39	104	....	....	..	28.4	....	....	....
20		"	A	"	a	First	"	13	0.3	24-36	..	30.1	540	100	163
21		"	C	"	....	Random	9-25-39	20	1.4	16-55	61	25.3	4554	2960	1152
22		"	B	"	b	First	"	16	1.0	20-35	69	25.4	1662	735	422
23		"	A	"	ac	Second	"	13	1.1	8-15	80	23.7	220	56	52
24		"	ABC	Third	s	Random	7-16-40	133	....	....	..	29.2	....	....	....
25		"	ABC	"	s	"	9-27-40	133	....	....	..	27.4	....	....	....
26		W1	A	First	....	First	8-24-38	23	1.2	....	72	26.1	514	196	134
27		"	B	"	....	"	10-18-38	25	1.3	26	63	23.5	694	402	163
28		"	C	Second	....	"	7-27-39	10	....	12-42	74	28.2	2135	466	602
29		"	B	"	b	Random	"	25	....	....	..	26.4	....	....	....
30		"	D	"	....	First	9-25-39	15	0.9	28-66	52	21.5	3005	2812	646
31		"	B	"	b	"	"	25	1.9	10-66	55	20.6	1308	1092	269
32		"	C	"	c	Second	"	10	2.4	2-16	82	20.3	243	54	49
R. glabra															
33	Seed.....	F1	G	First	....	First[5]	8-24-38	8	1.9	....	77	16.0	1192	347	191
34		"	H	"	....	"	10-18-38	3[7]	1.0	24	73	17.1	2623	965	449
35		"	KL	Second	....	Random	7-26-39	21	....	....	..	23.2	....	....	....
36		"	H	"	b	"	"	9	....	....	..	19.7	....	....	....
37		"	KL	"	....	"	9-25-39	21	0.7[8]	24-58	61	21.0	4800[8]	3126[8]	1008[8]
38		"	H	"	b	First	"	9	1.6	20-66	45	19.1	2801	3477	535
39		"	L	Third	d	"	7-16-40	9	....	40	68	23.7	5096	2366	1208
40		"	H	"	bd	"	"	9	....	40	72	23.1	3247	1295	750
41		"	K	"	d	"	9-27-40	6.5	....	28-60	55	25.2	5951	4857	1500
42	Root cuttings.....	F3	AB	First	....	"	8-24-38	33	1.1	....	83	17.2	1955	402	336
43		"	C	"	....	"	10-18-38	16	1.0	20	74	17.5	3296	1143	577

R. glabra															
44	Root cuttings.....	F3	B	First	a	Second	10-18-38	16	2.5	7	85	13.6	409	73	56
45		"	D	Second	....	Random	7-27-39	84	....	....	..	20.8	....	....	....
46		"	C	"	b	"	"	16	....	....	..	21.1	....	....	....
47		"	A	"	a	First	"	17	2.2	18-42	79	20.0	4747	1275	949
48		"	B	"	ab	"	"	16	1.3	18-30	81	25.2	3108	737	783
49		"	D	"	....	Random	9-25-39	20	1.8	12-48	72	19.2	5131	1962	985
50		"	C	"	b	First	"	16	3.8	18-56	61	18.2	6989	4413	1272
51		"	A	"	ac	Second	"	17	3.4	8-22	77	15.1	1612	475	243
52		"	B	"	abc	"	"	16	2.1	8-18	80	16.9	1011	247	171
53		"	ABCD	Third	[9]	Random	7-16-40	133	....	....	..	19.1	....	....	....
54		"	ABCD	"	[9]	"	9-27-40	133	....	....	..	21.4	....	....	....
55		W2	A	First	....	First	8-24-38	23	0.7	....	79	11.3	1689	451	191
56		"	B	"	....	"	10-18-38	25	0.8	28	70	18.2	1140	501	207
57		"	C	Second	....	"	7-27-39	10	2.6	12-24	84	21.0	3633	705	763
58		"	B	"	b	Random	"	25	....	....	..	20.1	....	....	....
59		"	D	"	....	First	9-25-39	15	2.2	8-33	75	19.6	3851	1299	755
60		"	B	"	b	"	"	25	0.7	12-53	63	19.7	2160	1251	426
61		"	C	"	c	Second	"	10	1.8	3-15	86	21.2	778	123	165
R. typhina															
62	Seed.....	F1	MN	First	....	First	8-24-38	12	4.3	....	67	15.7	1233	597	194
63		"	O	"	....	"	10-18-38	9	3.1	41	48	14.7	1449	1602	213
64		"	M	"	a	Second	"	6	4.5	7	..	13.8	200	544	28
65		"	PR	Second	....	Random	7-26-39	15	....	....	..	14.7	....	....	....
66		"	O	"	b	"	"	9	....	....	..	16.1	....	....	....
67		"	N	"	a	First	"	6	3.0	24-72	59	17.9	2822	2004	505
68		"	M	"	ab	"	"	6	3.0	30-72	58	16.5	3212	2301	530
69		"	PR	"	....	Random	9-25-39	15	1.9	36-99	32	15.1	6646	14052	1004
70		"	O	"	b	First	"	9	7.1	84	36	14.8	8891	15615	1316
71		"	N	"	ac	Second	"	6	2.5	12-40	65	9.6	1014	541	97
72		"	M	"	abc	"	"	6	4.2	18-42	62	10.8	1799	1107	194
73		"	R	Third	d	First	7-16-40	8	....	75	48	15.2	7692	8299	1169
74		"	MN	"	abcd	"	"	10	....	75	61	21.2	2150	1363	456
75		"	P	"	d	"	9-27-40	10	....	25-91	31	14.8	6432	14539	952
76		"	R	"	de	Second	"	8	....	9-43	62	15.2	1655	1024	252
77	Root cuttings.....	W3	A	First	....	First	8-24-38	23	0.8	....	62	12.8	1351	825	173
78		"	B	"	....	"	10-18-38	25	1.1	60-80	42	14.3	2745	3828	393
79		"	C	Second	....	"	7-27-39	10	4.7	12-60	70	18.3	8491	3574	1554
80		"	B	"	b	Random	"	25	....	....	..	14.7	....	....	....
81		"	D	"	....	First	9-25-39	15	2.4	24-72	57	12.8	6665	5035	853
82		"	B	"	b	"	"	25	3.5	45-111	34	12.7	12305	23457	1563
83		"	C	"	c	Second	"	10	5.6	8-36	76	12.8	4162	1322	533

[1] A—cut 8-24-38, b—cut 10-18-38, c—cut 7-26-39, d—cut 9-25-39, e—cut 7-16-40. After taking samples on 9-25-39, all remaining portions of rows F1, F2, and F3 were cut; that is, on this date all plants in Section F were cut. Section W was abandoned at this time.

[2] First or second indicates that the cutting in question was the first or second made on those plants in the particular year involved rather than in the life of the plants. Random means that the plants were not cut but a leaf sample was taken for analysis by removing 2 or 3 leaves from all or some of the plants in the portion of the row involved. When per acre yields are given in such cases the row was cut sometime after the random sampling and the yield data thus obtained.

[3] In those cases where there was only random sampling, as indicated in the column "Cutting for season" and no cutting was made, the figures refer to the length of row sampled.

[4] Calculated on air-dry basis.

[5] All of row cut 9-25-39, 104 feet for first time, 16 feet for second, and 13 feet for third time.

[6] Plants died after first cutting.

[7] A 9-foot section of the row was assigned to this cutting but only 3 feet of it were occupied by plants.

[8] Not over one-half of the row was occupied, yield figures should therefore be doubled.

[9] All of row cut 9-25-39, 84 feet for first time, 16 feet for second time, 17 feet for third, and 16 feet for fourth time.

R. glabra																
41	Seed.....	d	First	9-27-40	61	47	1.6	50.3	25.1	25.2	50	...	....	....	...	..
42	Root cuttings..	....	"	8-24-38	70	75	1.1	39.2	22.0	17.2	44	1.9	20.2	18.2	2.0	10
43		....	"	10-18-38	65	54	2.1	40.9	23.4	17.5	43	2.2	22.5	18.6	3.9	17
44		a	Second	"	74	72	1.2	38.1	24.5	13.6	36	2.3	32.4	27.5	4.9	15
45		....	Random	7-27-39	63	..	1.8	43.1	22.3	20.8	48	...	....	....	...	..
46		b	"	"	67	..	1.9	43.2	22.1	21.1	49	...	....	....	...	..
47		a	First	"	68	68	2.2	43.5	23.5	20.0	46	1.6	19.2	16.4	2.8	15
48		ab	"	"	66	67	2.0	45.7	20.5	25.2	55	1.7	21.4	17.9	3.5	16
49		....	Random	9-25-39	61	69	2.1	42.8	23.6	19.2	45	...	....	....	...	..
50		b	First	"	62	50	1.9	40.7	22.5	18.2	45	1.7	18.1	14.9	3.2	18
51		ac	Second	"	68	63	1.6	38.2	23.1	15.1	40	1.9	22.2	16.4	5.8	26
52		abc	"	"	68	64	1.3	41.9	25.0	16.9	40	2.0	24.4	17.6	6.8	28
53		[2]	Random	7-16-40	..	..	1.5	41.2	22.1	19.1	46	...	....	....	...	..
54		[2]	"	9-27-40	..	..	1.7	47.1	25.7	21.4	45	...	....	....	...	..
55		....	First	8-24-38	75	84	1.0	33.7	22.4	11.3	34	0.7	19.1	16.8	2.3	12
56		....	"	10-18-38	66	61	1.8	40.9	22.7	18.2	45	2.2	24.2	19.0	5.2	22
57		....	"	7-27-39	68	71	2.1	41.2	20.2	21.0	51	1.6	18.5	15.0	3.5	19
58		b	Random	"	72	..	1.2	39.0	18.9	20.1	52	...	....	....	...	..
59		....	First	9-25-39	68	53	2.3	39.1	19.5	19.6	50	2.1	19.0	14.5	4.5	24
60		b	"	"	71	53	1.8	39.8	20.1	19.7	50	1.6	18.0	12.3	5.7	32
61		c	Second	"	70	70	1.3	42.2	21.0	21.2	50	1.9	22.3	16.6	5.7	26
R. typhina																
62	Seed.....	....	First	8-24-38	73	75	1.6	39.7	24.0	15.7	40	1.6	15.1	13.9	1.2	8
63		....	"	10-18-38	66	50	2.3	41.4	26.7	14.7	36	2.7	20.3	17.2	3.1	15
64		a	Second	"	71	..	1.4	39.5	25.7	13.8	35	...	....	....	...	..
65		....	Random	7-26-39	66	..	2.0	37.4	22.7	14.7	39	...	....	....	...	..
66		b	"	"	68	..	2.3	37.9	21.8	16.1	43	...	....	....	...	..
67		a	First	"	71	68	2.1	40.0	22.1	17.9	45	2.0	13.2	12.3	0.9	7
68		ab	"	"	71	69	1.7	38.4	21.9	16.5	43	2.1	12.7	11.6.	1.1	9
69		....	Random	9-25-39	65	46	2.7	39.0	23.9	15.1	39	...	....	....	...	..
70		b	First	"	63	47	2.2	38.7	23.9	14.8	38	1.8	14.4	12.7	1.7	12
71		ac	Second	"	71	63	1.4	36.8	27.2	9.6	26	1.9	17.8	14.7	3.1	17
72		abc	"	"	72	66	1.9	36.2	25.4	10.8	30	1.6	15.3	12.6	2.7	18
73		d	First	7-16-40	72	68	2.0	38.0	22.8	15.2	40	...	....	....	...	..
74		abcd	"	"	73	72	2.2	43.1	21.9	21.2	49	...	....	....	...	..
75		d	"	9-27-40	62	39	1.8	42.1	27.3	14.8	35	...	....	....	...	..
76		de	Second	"	71	60	1.5	42.8	27.6	15.2	36	...	....	....	...	..
77	Root cuttings..	....	First	8-24-38	73	75	1.9	37.2	24.4	12.8	34	0.8	13.7	12.1	1.6	12
78		....	"	10-18-38	65	51	2.4	39.3	25.0	14.3	36	1.6	16.1	13.1	3.0	19
79		....	"	7-27-39	66	66	2.0	38.3	20.0	18.3	48	2.0	13.0	11.7	1.3	10
80		b	Random	"	71	..	1.9	34.6	19.9	14.7	43	...	....	....	...	..
81		....	First	9-25-39	66	49	2.4	34.2	21.4	12.8	37	1.5	14.8	11.9	2.9	20
82		b	"	"	68	51	2.5	33.5	20.8	12.7	38	1.5	9.8	8.2	1.6	16
83		c	Second	"	70	66	2.0	34.6	21.8	12.8	37	1.9	14.6	11.5	3.1	21

[1] See Table I.

[2] See Table I.

Purity of extractive is the amount of tannin expressed as percentage of the amount of soluble solids.

TABLE II. Effect of age of plant, cutting history and date of sampling on tannin content of three species of sumac grown from seed or root cuttings on two soil types in Sections F and W at Arlington Experiment Farm, Arlington, Virginia, in 1938-1940

Species of Rhus and Sample No.	Grown from	Cutting History[1]	Cutting for Season[2]	Date of Sampling	Moisture in Fresh		ANALYSIS ON MOISTURE-FREE BASIS									
							LEAVES					STEMS				
					Leaves	Stems	Insolubles	Soluble Solids	Non-tannin	Tannin	Purity of Extractives[3]	Insolubles	Soluble Solids	Non-tannin	Tannin	Purity of Extractives[3]
					%	%	%	%	%	%	%	%	%	%	%	%
R. copallina																
1	Seed.....	....	First	8-24-38	74	75	0.8	36.6	22.9	13.7	37	1.9	18.5	16.4	2.1	11
2		....	"	10-18-38	67	53	1.2	39.0	24.0	15.0	39	2.6	19.1	15.6	3.5	18
3		a	Second	"	73	..	0.9	41.4	27.1	14.3	35	...	....	....	...	..
4		....	Random	7-26-39	66	..	2.4	37.8	19.9	17.9	47	...	....	....	...	..
5		b	"	"	..	..	1.3	36.6	19.0	17.6	48	...	....	....	...	..
6		a	First	"	69	67	0.5	38.4	20.1	18.3	48	1.6	13.5	12.1	1.4	10
7		ab	"	"	70	68	0.7	38.3	20.1	18.2	48	1.8	14.7	13.2	1.5	10
8		....	Random	9-25-39	64	45	2.1	37.4	22.1	15.3	41	...	....	....	...	..
9		b	First	"	63	52	2.2	40.0	23.3	16.7	42	2.4	12.1	10.4	1.7	14
10		ac	Second	"	70	67	0.8	39.0	24.1	14.9	38	1.7	16.8	13.8	3.0	18
11		abc	"	"	71	67	0.7	39.4	23.5	15.9	40	2.4	18.1	15.1	3.0	17
12		d	First	7-16-40	70	63	1.1	41.9	21.1	20.8	50	...	....	....	...	..
13		abcd	"	"	68	66	2.0	44.3	23.0	21.3	48	...	....	....	...	..
14		d	"	9-27-40	64	49	2.5	44.0	24.8	19.2	44	...	....	....	...	..
15		de	Second	"	75	70	0.7	43.8	24.0	19.8	45	...	....	....	...	..
16		abcde	"	"	78	73	0.4	40.2	22.8	17.4	43	...	....	....	...	..
17	Root cuttings..	....	First	8-24-38	67	70	1.3	46.6	21.4	25.2	54	3.5	25.5	23.0	2.5	10
18		....	"	10-18-38	61	53	1.7	49.8	22.6	27.2	55	2.6	19.2	15.6	3.6	19
19		....	Random	7-26-39	64	..	1.7	49.4	21.0	28.4	58	...	....	....	...	..
20		a	First	"	..	76	1.6	50.2	20.0	30.1	60	2.4	18.4	15.3	3.1	17
21		....	Random	9-25-39	60	..	2.0	49.7	24.4	25.3	51	...	....	....	...	..
22		b	First	"	59	52	1.7	48.5	23.1	25.4	52	2.1	15.5	12.4	3.1	20
23		ac	Second	"	67	62	1.1	48.6	24.9	23.7	49	2.8	25.1	18.2	6.9	28
24		s	Random	7-16-40	..	..	1.5	51.2	22.0	29.2	57	...	....	....	...	..
25		s	"	9-27-40	..	..	1.8	53.2	25.8	27.4	52	...	....	....	...	..
26		....	First	8-24-38	70	72	1.3	46.7	20.6	26.1	55	1.7	18.9	16.3	2.6	14
27		....	"	10-18-38	64	54	1.4	47.5	24.0	23.5	50	2.2	16.3	13.1	3.2	20
28		....	"	7-27-39	69	65	1.6	48.4	20.2	28.2	58	1.6	14.4	11.8	2.6	18
29		b	Random	"	73	..	1.6	45.7	19.3	26.4	58	...	....	....	...	..
30		....	First	9-25-39	68	48	1.4	42.9	21.4	21.5	50	2.0	13.4	11.6	1.8	13
31		b	"	"	67	56	1.3	42.9	22.3	20.6	48	2.2	12.0	10.4	1.6	13
32		c	Second	"	70	66	1.2	47.5	27.2	20.3	43	2.8	25.5	19.2	6.3	25
R. glabra																
33	Seed.....	....	First[4]	8-24-38	72	80	1.1	39.8	23.8	16.0	40	2.3	23.7	21.8	1.9	8
34		....	"	10-18-38	63	55	1.9	41.3	24.2	17.1	41	2.3	19.6	15.1	4.5	23
35		....	Random	7-26-39	65	..	1.5	42.9	19.7	23.2	54	...	....	....	...	..
36		b	"	"	65	..	1.6	40.6	20.9	19.7	49	...	....	....	...	..
37		....	"	9-25-39	61	61	1.6	43.7	22.7	21.0	48	...	....	....	...	..
38		b	First	"	80	52	1.9	41.1	22.0	19.1	47	1.7	15.4	12.2	3.2	21
39		d	"	7-16-40	71	74	1.7	45.0	21.3	23.7	53	...	....	....	...	..
40		bd	"	"	70	77	1.6	45.1	22.0	23.1	51	...	....	....	...	..

TABLE III. Leafiness[1] and tannin content of leaves from three species of sumac harvested twice within a season and in two successive seasons in sections F and W at Arlington Experiment Farm, Arlington, Virginia, in 1938-1940

Species	Comparisons	Plants Grown from	Earlier Sample Number	Later Sample Number	Corresponding Dates	Corresponding Percent of Leaves (Leafiness)	Corresponding Percent Tannin in Leaves	Change in Percent: Leafiness	Change in Percent: Tannin
R. copallina	Within season	Seed	1	3	8-24-38 10-18-38	74 —	13.7 14.3		+
			6	10	7-26-39 9-25-39	67 76	18.3 14.9	+	−
			7	11	7-26-39 9-25-39	69 77	18.2 15.9	+	−
			12	15	7-16-40 9-27-40	56 70	20.8 19.8	+	−
			13	16	7-16-40 9-27-40	74 74	21.3 17.4	±	−
		Root cuttings	20	23	7-26-39 9-25-39	— 80	30.1 23.7	[2]	−
			28	32	7-27-39 9-25-39	74 82	28.2 20.3	+	−
	Between seasons	Seed	1	6	8-24-38 7-26-39	74 67	13.7 18.3	−	+
			2	9	10-18-38 9-25-39	64 55	15.0 16.7	−	+
			7	13	7-26-39 7-16-40	69 74	18.2 21.3	+	+
		Root cuttings	17	20	8-24-38 7-26-39	84 —	25.2 30.1	[2]	+
			18	22	10-18-38 9-25-39	75 69	27.2 25.4	−	−
			27	31	10-18-38 9-25-39	63 55	23.5 20.6	−	−
R. glabra	Within season	Root cuttings	42	44	8-24-38 10-18-38	83 85	17.2 13.6	−	−
			47	51	7-27-39 9-25-39	79 77	20.0 15.1	−	−
			48	52	7-27-39 9-25-39	81 80	25.2 16.9	−	−
			57	61	7-27-39 9-25-39	84 86	21.0 21.2	+	+
	Between seasons	Seed	34	38	10-18-38 9-25-39	73 45	17.1 19.1	−	+
		Root cuttings	42	47	8-24-38 7-27-39	83 79	17.2 20.0	−	+
			43	50	10-18-38 9-25-39	74 61	17.5 18.2	−	+
			44	52	10-18-38 9-25-39	85 80	13.6 16.9	−	+
			56	60	10-18-38 9-25-39	70 63	18.2 19.7	−	+
R. typhina	Within season	Seed	62	64	8-24-38 10-18-38	67 —	15.7 13.8	[2]	−
			67	71	7-26-39 9-25-39	59 65	17.9 9.6	+	−
			68	72	7-26-39 9-25-39	58 62	16.5 10.8	+	−
			73	76	7-16-40 9-27-40	48 62	15.2 15.2	+	±
		Root cuttings	79	83	7-27-39 9-25-39	70 76	18.3 12.8	+	−
	Between seasons	Seed	62	67	8-24-38 7-26-39	67 59	15.7 17.9	−	+
			63	70	10-18-38 9-25-39	48 36	14.7 14.8	−	+
			64	72	10-18-38 9-25-39	— 62	13.8 10.8	[2]	−
			67	74	7-26-39 7-16-40	59 61	17.9 21.2	+	+
		Root cuttings	78	82	10-18-38 9-25-39	42 34	14.3 12.7	−	−

Leafiness refers to the percentage of leaves in the material harvested consisting of leaves and stems.

[2]No comparable data.

TABLE IV. Average leafiness and tannin content and calculated per acre yields of leaves and leaf tannin from three species of sumac grown from seed and root cuttings in Sections F and W at Arlington Experiment Farm, Arlington, Virginia, 1938-40

Species	Plants Grown from	No. of Tests[1]	Average Leafiness	Average Tannin Content of Leaves	Calculated Yield per Acre					
					Leaves			Leaf Tannin		
					Highest	Lowest	Average	Highest	Lowest	Average
			percent	*percent*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
Rhus copallina	Seed.....	13	65	17.4	7706	691	3036	1178	120	534
Rhus glabra	Seed.....	7	64	20.7	5951	1192	3673	1500	191	806
Rhus typhina	Seed.....	12	52	15.1	8891	1014	3750	1316	97	574
Rhus copallina	Root cuttings.....	10	69	25.3	4554	514	1696	1152	134	423
Rhus glabra	Root cuttings.....	14	76	18.6	6989	778	2936	1272	165	559
Rhus typhina	Root cuttings.....	6	57	14.0	12305	1351	5953	1563	173	845

[1] Data for samples numbered 3, 23, 32, 44, and 64 (see Table I) have been omitted in preparing this table. These samples were second cuttings during the first season of growth, and also both second cuttings during the second season for *copallina* plants grown from root stock. The plants made very poor recovery after the first cutting and yields of tannin per acre were less than 100 pounds.

Tannin content as affected by various conditions and procedures. Although the plantings of root cuttings in 1938 were made on two soil types, as stated, the size of the plantings was too limited and the number of analyses too few to permit any conclusions concerning significant differences in the yield and quality of the harvested materials that can clearly be attributed to soil differences. Consequently other comparisons have been made without reference to the two specific locations. These comparisons are made on the basis of both quality and yields. They are in both cases, first, between early and late growth within a season, that is, between the material that can be harvested in late July and that which develops from the stumps between then and late September, and second, between growth in two successive seasons, that is, material harvested in late fall and again the following fall or in midsummer of one year and again the following midsummer. The above comparisons are made on plantings from seed and from root cuttings.

In the case of seedlings grown in 1939, the effects of more variations in harvesting dates on quality, yields, and subsequent growth can be compared and special opportunity is afforded to compare the tannin content on the basis of the source of the seed from which the plants were grown.

From an inspection of Table II, it is immediately evident that for some reason the tannin content of the leaves from all three species under all the conditions involved in the experimental plantings started in 1938 is far below that usually reported for leaves collected from plants growing wild. This is particularly true of the seedlings of all three species and of *R. glabra* and *R. typhina* grown from root cuttings on both soil types. Thus out of 16 samples of *R. copallina* seedlings started in 1938 and growing through 1939 and 1940, only two samples, both obtained from 1940 growth, contained more than 20 per cent tannin and these contained only 20.8 and 21.3 per cent. In three samples the percentage was less than 15 per cent and the average of the 16

TABLE V. Analysis of leaves of three species of sumac grown from seed from several localities in 1939 in Section E at Arlington Experiment Farm, Arlington, Virginia

Species	Number	Source of Seed	Rows	Date of Sampling	Analysis on Moisture-free Basis				
					Insolubles	Soluble Solids	Non-tannin	Tannin	Purity[1]
					percent	*percent*	*percent*	*percent*	*percent*
Rhus copallina	84	Halifax, Va.	1-6	9-15-39	1.7	51.0	23.2	27.8	55
	85	"	1	7-15-40	1.7	53.8	21.7	32.1	60
	86	"	1	9-6-40	1.7	53.6	23.6	30.0	56
	87	"	2	7-15-40	1.3	53.9	22.1	31.8	59
	88	"	2	9-6-40	1.4	52.7	24.0	28.7	54
	89	"	2	6-25-41	1.1	54.0	22.1	31.9	59
	90	"	3-6	7-15-40	1.5	57.1	21.3	35.8	63
	91	"	3-6	9-6-40	2.5	55.2	24.5	30.7	56
	92	"	3-6	6-25-41	1.3	56.5	21.4	35.1	62
	93	Rockingham, N. C.	7-12	9-15-39	1.9	41.6	25.6	16.0	38
	94	"	7-8	7-15-40	2.8	40.0	21.6	18.4	46
	95	"	7-8	9-6-40	3.7	43.5	24.0	19.5	45
	96	"	9-12	7-15-40	2.3	38.8	21.0	17.8	46
	97	"	9-12	9-6-40	2.5	40.8	21.6	19.2	47
	98	"	7-12	6-25-41	3.0	40.9	21.6	19.3	47
Rhus glabra	99	Macon, Ga.	13-16	9-15-39	1.3	42.1	22.9	19.2	46
	100	"	13-16	7-15-40	2.7	54.2	23.0	31.2	58
	101	"	13-16	9-6-40	1.7	51.3	22.3	29.0	57
	102	"	13-16	6-25-41	1.2	52.4	22.2	30.2	58
	103	Athens, Ga.	17-20	9-15-39	1.6	39.8	20.9	18.9	47
	104	"	17	7-15-40	1.7	43.6	24.9	18.7	43
	105	"	17	9-6-40	1.7	43.9	22.2	21.7	49
	106	"	18	7-15-40	2.8	50.5	23.8	26.7	53
	107	"	18	9-6-40	1.6	48.1	22.4	25.7	53
	108	"	19-20	7-15-40	1.8	51.3	21.0	30.3	59
	109	"	19-20	9-6-40	1.1	48.5	22.2	26.3	54
	110	"	17-20	6-25-41	1.2	49.6	23.4	27.2	55
	111	Winston-Salem, N. C.	21-24	9-15-39	1.4	42.5	21.3	21.2	50
	112	"	21-24	7-15-40	2.1	53.8	22.7	31.1	58
	113	"	21-24	9-6-40	1.4	53.0	23.0	30.0	57
	114	"	21-24	6-25-41	1.4	53.7	22.5	31.2	58
Rhus typhina	115	Western Maryland	25-36	9-15-39	1.6	36.5	22.9	13.6	37
	116	"	25, 27	7-15-40	1.7	43.4	23.4	20.0	46
	117	"	25, 27	9-6-40	2.1	44.1	23.9	20.2	46
	118	"	26	7-15-40	2.1	42.1	25.0	17.1	41
	119	"	26	9-6-40	1.7	41.0	23.4	17.6	43
	120	"	28	9-6-40	1.8	42.5	24.4	18.1	43
	121	"	28-36	7-15-40	1.8	46.8	21.6	25.2	54
	122	"	29-36	9-6-40	2.2	44.5	24.4	20.1	45
	123	"	29-36	6-25-41	1.6	43.2	23.5	19.7	46

[1] See footnote 4—Table I.

TABLE VI. Harvesting data from three species of sumac grown from seed planted in May in Section E and harvested in September, 1939 at Arlington Experiment Farm, Arlington, Virginia

Species	Date Harvested	Area Harvested	Average No. Plants per Ft. of Row	Length of Stems	Moisture in Fresh		Leafiness	Tannin in Leaves[1]	Calculated per Acre Yield of Moisture Free		
					Leaves	Stems			Leaves	Stems	Leaf Tannin
Rhus copallina	9-26-39	*acres* .06	4.1	*inches* 24	*percent* 66	*percent* 62	*percent* 81	*percent* 27.8	*pounds* 996	*pounds* 239	*pounds* 277
Rhus glabra	9-26-39	.01	1.5	12-36	69	67	76	21.2	1391	446	295
Rhus typhina	9-26-39	.01	0.7	18-48	70	64	68	13.6	899	431	122

[1] The material cut on September 26 was not sampled but portions of the same areas were sampled for analysis 11 days earlier. The tannin content at that time is used in calculating the per acre yield of leaf tannin.

samples was 17.3 per cent. Relatively the seedlings of *R. glabra,* which averaged 20.8 per cent, were of better quality. In 5 out of 9 cases the tannin content was above 20 per cent while the lowest found was 16.0 per cent. The *R. typhina* seedlings were also of poor quality. Only one out of 15 samples contained more than 20 per cent, one contained 10.8, another only 9.6, and the average was 15.1 per cent.

The vegetatively propagated plants of *R. copallina* were much richer in tannin than the seedlings though on the whole the tannin content was lower than that of uncultivated plants. In 16 samples which averaged 25.4 per cent, representing three seasons, the tannin content ranged from 20.3 to 30.1 per cent. In the case of *R. glabra* the range in 20 samples was from 11.3 to 25.2 per cent and the average 18.8 per cent. On the whole this indicates a poorer quality than that of the seedlings of these species. This is also true of *R. typhina,* 7 samples of which averaged 14.0 per cent.

The reason for the low tannin content of most of the material obtained from these plantings cannot be determined from the information at hand. Three conditions are involved, any one or all of which could have a modifying effect on the quality of the plants, namely, the type and condition of the soil, the strain of the parent plants from which the seed or roots were obtained, and the age of the plants or of the particular material sampled. The root cuttings of *R. copallina* used in these plantings were obtained from a large clump of plants in Charles County, Maryland, which had previously been tested a number of times and found to contain well over 30 per cent of tannin. From this it would appear that some environmental factor, possibly soil fertility or condition, was responsible for the reduced tannin content of the plantings. The soil in Section W. was quite rich, at least in organic matter, that in the location from which the roots were originally obtained was probably poorest, and that in Section F. intermediate in fertility. The average tannin contents of seven samples of *R. copallina* taken from each section on the same dates were for Section W 23.8 per cent, and for Section F 26.5 per cent. Other factors, however, were not strictly comparable. In the original location the plants were in competition with grass and other vegetation while in the plant-

TABLE VII. Effect of cutting plants of three species of sumac grown from seed in 1939 in Section E at Arlington Experiment Farm, Arlington, Virginia, on the condition and growth of the plants the following year

Species	Source of Seed	Treatment in 1939	CONDITION AND GROWTH OF PLANTS IN 1940					
			May 10		June 3		September 6	
			Condition	New Growth	Condition	New Growth	Condition	New Growth
				inches		*inches*		*inches*
Rhus copallina	Halifax, Va.	(a) cut Sept. 26	Some dead	2-3	Uneven; many dead	4-15	Tallest are single shoots	24-48
		(b) cut Oct. 16	.....	3-4	Very uniform; some dead	10-20	Many flower heads	48-54
		(c) uncut	.....	6	.....	12-36	Many flower heads; bushier; heavier stems than (b)	42-48
	Rockingham, Va.	(d) cut Sept. 26	Many dead	1-2	Uneven	4-12	.....	24-36
		(e) cut Oct. 16	Some dead	1-2	.....	6-15	.....	24-42
Rhus glabra	Athens, Ga., and Winston Salem, N. C.	(f) cut Sept. 26	A few dead	5-6	.....	8-12	.....	36-48
	Macon, Ga.	(g) cut Oct. 16	.....	5-6	.....	12-30	.....	54-66
	Athens, Ga.	(h) uncut	.....	5-6	.....	24-60	.....	60-72
Rhus typhina	Western Maryland	(i) cut Sept. 26	Some dead	3-8	.....	12-30	.....	48-60
		(j) cut Oct. 16	More uniform than (i)	3-8	.....	18-36	.....	48-60
		(k) uncut	Very uniform	4-6	.....	36-66	.....	60-72

TABLE VIII. Tannin content of leaves of three species of sumac grown from seed in Section E at Arlington Experiment Farm, Arlington, Virginia, in 1939 over a three-year period in relation to the geographic source of the seed and various harvesting dates.

Rhus copallina

Source of seed sown May, 1939	Row No.	Date of cutting in 1939	Percentage of tannin in leaves collected on: Sept. 15, 1939	July 15, 1940	Sept. 6, 1940	June 25, 1941
Halifax, Va.	1	Uncut		32.1	30.0	....
	2	Oct. 16		31.8	28.7	31.9[1]
	3	Sept. 26	27.8			
	4	"		35.8	30.7	35.1[2]
	5	"				
	6	"				
Rockingham, N. C.	7	"		18.4	19.5	
	8	"				
	9	Oct. 16	16.0			19.3
	10	"		17.8	19.2	
	11	"				
	12	"				

Rhus glabra

Source of seed sown May, 1939	Row No.	Date of cutting in 1939	Percentage of tannin in leaves collected on: Sept. 15, 1939	July 15, 1940	Sept. 6, 1940	June 25, 1941
Macon, Ga.	13	Oct. 16				
	14	"	19.2	31.2	29.0	30.2
	15	"				
	16	"				
Athens, Ga.	17	Uncut		18.7	21.7	
	18	Oct. 16	18.9	26.7	25.7	27.2
	19	Sept. 26		30.3	26.3	
	20	"				
Winston Salem, N. C.	21	"				
	22	"	21.2	31.1	30.0	31.2
	23	"				
	24	"				

Rhus typhina

Source of seed sown May, 1939	Row No.	Date of cutting in 1939	Percentage of tannin in leaves collected on: Sept. 15, 1939	July 15, 1940	Sept. 6, 1940	June 25, 1941
Western Maryland	25	Oct. 16		20.0	20.2	....
	26	Uncut		17.1	17.6	....
	27	Oct. 16		20.0	20.2	....
	28	Sept. 26			18.1	....
	29	"				
	30	"	13.6			
	31	"				
	32	"		25.2	20.1	19.7
	33	"				
	34	"				
	35	"				
	36	"				

[1]On this date the sample from Row 2 was obtained from 70 feet of row instead of 133 feet as in all other cases.

[2]On this date the sample from Rows 3 to 6 was obtained from about two-fifths of the area previously sampled.

TABLE IX. Effect of date of cutting in fall on tannin content of three species of sumac in midsummer of the following year in Section E, Arlington Experiment Farm, Arlington, Va.

Species and Source of Seed	Rows Cut[1]	QUALITY OF LEAVES ON JUNE 25, 1941					
		First 20 Feet Cut on Sept. 6, 1940		Second 20 Feet Cut on Oct. 10, 1940		Third 20 Feet Cut on Nov. 8, 1940	
		Tannin	Purity[2]	Tannin	Purity[2]	Tannin	Purity[2]
		percent	*percent*	*percent*	*percent*	*percent*	*percent*
Rhus copallina							
Halifax, Va.	1, 2, 3	35.4	61	29.9	58	30.7	58
Rhus glabra							
Macon and Athens, Ga.	13, 17, 20	30.1	56	27.8	55	29.8	57
Rhus typhina							
Western Maryland	26, 27, 28	25.0	51	24.7	50	25.2	56

[1] In 1939 one row of each species was cut September 26, another October 16, and the third was left uncut.

[2] See footnote 1, Table II.

ings the soil was kept loose and free from weeds by cultivation. The effect of these factors is unknown.

The roots of *R. glabra* and *R. typhina* came from localities where the plants had not been tested for tannin content. The seed of each species planted was collected in a single locality but may have been obtained from various clones. Since its origin is uncertain it cannot be assumed that a single strain of each species is represented in these plantings, hence as in the case of the root propagated plants it cannot be determined to what extent, if any, the low tannin content is a genetic character. From the data developed from this experiment it could be assumed that the low tannin content is due primarily to the fact that the plants were all young and the material harvested in some cases represented only a half season's growth. This assumption is open to question because in other instances a much higher tannin content was found in young plants of these species. The plants grown from seed in 1939, in Section E, which will be discussed later, afforded a better opportunity to determine the importance of age and genetic origin as factors affecting tannin content.

A number of comparisons can be made in connection with the plantings made in 1938 as shown by the data in Table III. It is seen that with few exceptions the tannin content of the leaves is higher when the plants are cut in midsummer than when the second growth is cut in late summer or fall, regardless of the species, whether seed or root cuttings are used or whether the two cuttings are made in the season in which the plants are planted or in the following season. This is probably due in part to the decline in tannin content that generally occurs in the leaves as the end of the growing season approaches and partly to the material being new growth developed since midsummer. Although the available data pertain to only three seasons it is a reasonable assumption that such a difference in tannin content of leaves from two successive cuttings made at the two periods within a season may be

expected in any season regardless of the age of the plants. It follows, therefore, that regardless of species or method of propagation, if two crops of sumac are harvested during a season by cutting the plants near the ground in midsummer and permitting new growth to develop by fall, material of relatively poorer quality will be obtained from the late harvest.

It appears also that the tannin content is higher in the second season than in the first season, especially if the plants are grown from seed, but this difference between seasons in this respect may be expected to be less pronounced or disappear as the plants get older.

Stems, as can be noted from Table II, are all quite low in tannin. The range in tannin content is from 0.9 to 6.9 per cent with an average of 3.1 per cent. The purity of the soluble solids is also very low, the average for all samples being only 16.9 per cent.

There appears to be a seasonal increase in tannin. The average tannin content of stems collected in July and August is 2.1 per cent, whereas it is 3.7 per cent for those collected in September and October. This change is just the reverse of that which occurs in the leaves, for leaves decrease in tannin as the season advances.

All of the stem samples examined, however, contain such a small amount of tannin and would yield an extract of such low purity that their presence in the commercial product would be undesirable. They may be considered only as an adulterant of the leaves.

Yields of leaves, stems and leaf tannin under various conditions and procedures. The percentage of leaf in the harvested material, which may be referred to as leafiness, is also of interest from a practical standpoint. Although it is entirely feasible to separate the large stems and even all the stems from the leaves in the dried material, as is done in Europe with Sicilian sumac, to handle a very bulky crop in the fresh condition and to dry it in a satisfactory manner involves considerable expense. Unless some means can be found of separating the stems at the time when the crop is cut rather than after it has been dried those species that produce the largest ratio of leaves to stems are most desirable if mechanical handling of the crop is contemplated. If such species also have the highest per cent of tannin in the leaves and the yield per acre is not too low they are especially suited to commercial culture.

When sumac plants are cut to leave a short stump new shoots develop from these stumps the following spring or in the same season if the plants are cut early enough. Of course, such new growth has stems of smaller diameter than the original stems would have had if they had not been cut. Consequently the leafiness of a crop depends to a large extent on the previous handling of the plants. Related to the importance of leafiness with regard to the value of the material harvested is the ratio of leaflets to petioles which together make up the leaf. The petioles are much lower in tannin content than the leaflets. The leaves of *R. copallina* have a higher ratio of leaflets than

those of the other two species and this species is therefore the most desirable of the three from that standpoint.

In Table III, various comparisons of leafiness are made between successive cuttings within a season and in successive seasons. The data, on the whole, are inadequate to permit definite conclusions but two general trends may be noted. In the case of *R. copallina* and *R. typhina* grown from seed or root cuttings the second crop in a season is likely to be more leafy than the first one. All three species apparently are less leafy in the second season than in the season in which the seed or roots are planted.

The data on yield of leaves, stems and leaf tannin calculated on an acre basis at certain stages and as affected by certain practices are included in Table I and summarized in Table IV. Inasmuch as the areas or lengths of rows cut varied greatly and were in all cases limited, comparison of the yields is simplified by calculating the yields on an acre basis. The figures thus obtained are primarily for the purpose of comparing the yields resulting from certain practices rather than indicating what production may be expected from an acre of the cultivated plants. The data also serve to show the proportion of leaves and stems in the material obtained. Inasmuch as the stems never contain enough tannin to make their inclusion in the marketed materia desirable the yield of tannin per acre is calculated on the basis of leaf tannin only. The yield of leaf is the most important factor in determining total lea tannin, although the percentage of tannin in the leaves varies enough at time to affect the leaf tannin yield considerably.

Comparisons can be made of yields between species, between plants grow from seed and from cuttings, between harvests made within a season, an between harvests made in successive seasons. It must be pointed out tha these experiments deal mainly with these species under the conditions se forth in the first two years of the growth from seed or root cuttings. Difference between the yield and quality of the material harvested in these two seasor are naturally more pronounced than those likely to occur between the secon and third or between any two subsequent seasons after the plants are full established. A prospective grower would of course be interested in knowin the crop possibilities of these species in the first few years when the princip propagating costs occur.

When grown from root cuttings the average yield of leaf from *R. copalli* was about 58 per cent of that of *R. glabra* and 28 per cent of that of *R. typhin* but in leaf tannin this species yielded respectively approximately 76 and per cent of that of the other two species. When grown from seed the diff ences in yields from *R. copallina* and the other species are much less. produced approximately 79 and 90 per cent of the leaf yield and 66 and per cent of the leaf tannin yield obtained respectively from *R. glabra* and *typhina*. These comparisons do not indicate the relative value of the th species as a source of tannin. A large amount of leaf tannin produced

acre is of interest only if this is due to a high percentage of tannin in the leaves rather than to a large yield of leaves with a relatively low tannin content. A large production of low grade leaf per acre is of no significance because it is unprofitable to transport and extract such material and impossible to use it directly in powdered form for processes in which the powdered leaf is required.

The number of comparisons possible between crops within a season and between crops in successive seasons are too limited to permit definite conclusions but they suggest a general trend. Whether grown from root cuttings or seed the yield of leaf tannin per acre that developed up to the latter part of September after the plants were cut late in July was in all cases very much less than the yield obtained from the first cut of the season. That is, the second growth of the season is always much less than that which develops between spring and midsummer. Plants grown from seed would usually not make enough growth the first season to warrant cutting twice. Between successive seasons there was in all cases an increase in the calculated per acre yield of leaves, stems, and leaf tannin, based on comparisons between late October, 1938, the year in which the plantings were made, and the following September. These increases as observed were no doubt due mainly to the growth of the plant and its root system generally in the first few seasons. In subsequent seasons the yields will probably change little or will be determined largely by seasonal conditions.

As a measure of the relative desirability of a species, assuming it is acceptable to the trade with respect to its effect on leather, a high tannin content is the first requirement, a substantial yield of leaf per acre is the second and a high ratio of leaf to stem is the third. From these investigations it appears that in well established and sufficiently mature plantings *R. copallina* is the preferred species with regard to the first requirement and in most cases also with regard to the third. *R. glabra* is definitely better than *R. typhina* in percentage of tannin and the ratio of leaf to stem. The latter species may under most conditions be expected to produce the highest yield of harvested material containing, however, a larger proportion of stems and a lower leaf tannin content.

Further Studies of Growth Rate of Seedlings After Cutting on Various Dates in Previous Season and Comparison of Plants Grown from Seed from Different Localities.

Reference has been made to seed of the three species from several localities planted in Section E, at Arlington Experiment Farm in the spring of 1939. (Figs. III, IV and V) These plantings served two principal purposes. First, they provided a means of observing the rate and quality of growth in the second season after cutting the first season's growth in the preceding September and October, and, second, they afforded an opportunity to compare the quality of the plants in relation to the source of the seed.

FIGURE III. *Rhus copallina* grown from seed planted in Section E, Arlington Experiment Farm, Arlington, Virginia, spring of 1939, showing growth in 1940 (photograph June 22) as affected by cutting the plants 3 inches from the ground on different dates in 1939. First row on right was not cut, second row was cut October 16, remaining rows were cut September 26.

FIGURE IV. *Rhus glabra* grown from seed planted in Section E, Arlington Experiment Farm, Arlington, Virginia, spring of 1939, showing growth in 1940 (photographed June 22, 1940) as affected by cutting the plants 3 inches from the ground on different dates in 1939. Rows 1 to 4 from right and row 6 cut October 16, row 5 uncut, remaining rows cut September 26.

FIGURE V. *Rhus typhina* grown from seed planted in Section E, Arlington Experiment Farm, Arlington, Virginia, spring of 1939, showing growth in 1940 (photographed June 22, 1940) as affected by cutting the plants 3 inches from the ground on different dates in 1939. Row 1 at right (first stake) and row 3 cut October 16, row 2 uncut, remaining rows cut September 26.

The seed of the several species used in these experiments was obtained from the localities already mentioned and shown in Table V, in which all data on analyses of the leaves obtained from these plantings are included. Data on leafiness and per acre yields of leaves, stems and leaf tannin as calculated from small harvested areas of the three species are assembled in Table VI.

It will be noted that in leaf yield *R. typhina* is slightly inferior to *R. copallina* and greatly inferior to *R. glabra*. Inasmuch as it is also much lower in the tannin content of the leaves the leaf tannin yield is naturally very poor as compared with the other species. This relative worth of the three species in leaf tannin yield is true only in the first season from seed. In subsequent years the more rank growth of *R. typhina* will, of course, produce a large yield of leaf and, therefore, a substantially larger leaf tannin yield, especially if the tannin content of the leaf increases.

Relation of certain harvesting practices to subsequent growth, quality and survival. Table VII shows the survival of the plants of each species in 1940 and the condition of growth on May 10, June 3 and September 6, of that year, after cutting on September 26 and October 16 the preceding fall, and when not cut at all. The plants were cut about 4 inches from the ground. Those cut on September 26, 1939, all developed new growth 4 to 5 inches high before this was destroyed by frost. No new growth appeared on those cut October 16. The effects of these treatments were soon evident the following spring as indicated in the table. The plants on which new growth was killed by frost in the preceding fall were slower starting growth and some had died during the winter. Later, others which started growth also died. Only a few plants died where the cutting was too late in the fall to permit new growth before frost. It will be noted that throughout the summer the plants not cut in the fall made the most growth and this difference is indicated by the relative height of the plants as recorded on September 6, 1940. These observations suggest that with regard to the effect on the succeeding season's growth the first year's seedling crop must be cut at such a time that the new growth will harden enough to survive the winter or late enough so that no new late growth will develop in the fall. It is very probable that this is true irrespective of the age of the plants. As a rule sumac leaves harvested as late as October, especially those of *R. copallina* and *R. glabra*, have turned red and are undesirable for tanning. It appears, therefore, that if the future condition of the plants must be considered the crop must be cut no later than in August unless the material obtained as late as middle October in the region in question is acceptable to the trade.

The data relating to the tannin content of the leaves from the various plantings in this experiment under the several conditions are assembled in Table VIII. On September 15, 1939, before any of the plants were cut as indicated, random samplings were made of the three species from the several seed lots. Subsequently samples were again collected on July 15 and September

6, 1940 and on June 25, 1941. It is clearly shown that the tannin content increased greatly in the second year over the first year but remained about the same thereafter. This is especially true in the case of *R. glabra* and *R. typhina*. It will be recalled that the seedlings in Section F, discussed previously, which were all low in tannin content the first season, showed little improvement in the second and third years. The reason for this behavior as compared with that of the plants in Section E cannot be determined from the information at hand.

Some additional data on the effect of cutting the plants on various dates on the tannin content in subsequent years are shown in Table IX. In this case 20-foot sections of the rows cut in 1939 as indicated were cut on September 6, October 10 and November 8, 1940, and all growth was sampled June 25, 1941. In this case again a large proportion of the plants cut in September died and those that survived made slower growth in the spring and early summer of 1941, yet this apparently did not affect the tannin content unfavorably.

Relation of tannin content to the geographic source of the seed. An interesting feature of the experiments in Section E concerns the relation of the tannin content to the source of the seed. It has been assumed that the wide variations in the tannin content of a species that have been observed may be due to several factors and that the amount of tannin produced in the leaves may be largely a genetic character subject possibly to some modification by environmental conditions. If this is the case there should be a good opportunity to develop a type or strain by selection or breeding which will consistently produce high quality leaf. In these experiments the seed of the several species was collected in the localities already mentioned and shown in Table V. No attempt was made to obtain it in any of the localities from single clones, hence the seed in any or all cases may represent a number of clones. The seed of *R. typhina* was a mixed lot from several localities near Cumberland, Maryland. The plants of *R. glabra* grown from seed from three localities in North Carolina and Georgia were of about equal quality. The two plantings of *R. copallina*, however, differed greatly in tannin content as shown in Table IV. The plants from the seed from Halifax, Virginia, were much superior in this respect and remained that way through 1941. Those from the seed from Rockingham, North Carolina were very poor in tannin content the first year and at no time contained as much as 20 per cent of tannin.

These two plantings of *R. copallina* represented two distinct botanical types. Those from the seed from Halifax were completely glabrous and the stems were rough with numerous lenticels while those from the seed from Rockingham were slightly pubescent at the tips and lacking in lenticels. No variations from these two types could be found in the two respective plots. It may be mentioned here that the seedlings of this species in Section F, planted in 1938,

were of the same type as those from the seed from Rockingham and equally low in tannin content.

Many of the plants grown from the seed from Halifax were removed to the new Bureau of Plant Industry Station at Beltsville, Md., in 1941, and additional plantings were made there with root cuttings obtained from the plot. Leaf samples collected in 1942 from 15 of the individual plants transplanted ranged in tannin content from 28.6 to 37.1 per cent. Eight contained above 33 per cent and only two below 30 per cent.

The pronounced difference in the tanning value of the plants from the two lots of seed as indicated by tannin content does not necessarily mean that the two types as described always differ in tannin content to the same extent under all conditions. That is, it does not follow that planting stock, either seed or roots, selected on the basis of such botanical variations would assure a crop of superior quality. However, it clearly indicates that selection is a practical means of improving the quality of sumac and that the development of propagating stock of acceptable quality is necessary and desirable if the cultivation of sumac as a domestic source of tanning material is to be encouraged.

Summary

Investigations were begun to determine the practical possibilities of growing several native species of sumac as sources of tannin. *Rhus copallina*, the black or dwarf sumac, *R. glabra*, the white sumac, and *R. typhina*, staghorn sumac, were grown from seed and root cuttings on several soil types. The effects of harvesting the plants at certain stages once or oftener within a season and in successive seasons on the survival and subsequent vigor of the plants and the yield and tannin content and quality of the leaves were determined. The qualities of plants obtained from seed from several sections of the country were compared to determine the possibilitiy of developing strains with higher tannin content. The experiments were conducted at the Arlington Experiment Farm, Arlington, Va., over a three year period. The original plantings could not be held longer because the site was required for other purposes after the early summer of 1941. Desirable stock developed during these experiments was transferred to the new experiment station of the Bureau of Plant Industry, Soils, and Agricultural Engineering at Beltsville, Md., where the investigations are being continued.

Although the results of these experiments were not conclusive in some respects the data, on careful study, suggest certain trends and indications which have an important bearing on practical aspects of growing sumac as a tannin crop.

There is a seasonal change in tannin content. The samples taken in midsummer were higher in tannin than those collected near the end of the growing season. During the first three years of the plant's life the tannin content shows

an increase as a rule, especially if the plants were grown from seed. Data for older plants were not obtained.

Heredity or genetic factors also influence tannin content. All of the seedlings were low in tannin except one lot of *R. copallina* grown from seed from Halifax, Virginia. These plants differed in some botanical characters from those grown from seed obtained elsewhere. This indicates that it may be possible to locate strains that consistently have a high tannin content. Other factors doubtless also influence the tannin content although no conclusive data are available from this study. For example there is an indication that plants grown in rich soil have a lower tannin content than plants in poor soil.

The time at which a previous cutting or cuttings were made appeared to have a slight influence on the percentage of tannin in subsequent growth. Plants in one location cut early in the fall while they were still green and growing were higher in tannin the following summer than either uncut plants or those cut late in the season. However, the date of the late summer or fall cutting has a direct effect on the survival of the plant over winter and its vitality the following season.

There seems to be little if any relation between the tannin content and the total number of previous cuttings. The yield of leaf material and tannin at the end of the first year is greater from plants grown from rootstock than from those grown from seed, but is low for either type of stand. It is probably best to leave the plants uncut the first year in order to promote root development.

Two cuttings per year is not advisable for one or two year old plants because the second cutting does not yield enough to pay for the labor of handling. Whether or not two cuttings per year could be made on older plants with well developed root systems could not be determined before the experiments had to be terminated for the reason stated.

Stems were very low in tannin content. The highest value found was 6.9 per cent with a purity of 27.5 in *R. copallina* grown from seed. The average for all stem samples was 3.1 per cent. Considering the low tannin content, the very low purity and the color of the stems, it is evident that the removal of the stems from the material that is to be marketed greatly improves its quality.

Literature Cited

1. Anonymous. American Sumac. Report of the U. S. Commissioner of Agriculture for 1869, p. 230 (1870).
2. ———— (Collection of Sumac in Virginia). *J. Soc. Chem. Ind.*, Oct. 29, 1882. p. 388.
3. Belavsky, E. and J. Slama. Sumac and its cultivation for tanning purposes in CSR. *Technicka Hlidka Kozeluzska* **13**, 59 (1937).
4. Frey, R. W. and H. C. Reed. A practical glass extractor. *J.A.L.C.A.*, **23**, 124 (1928).
5. Frey, R. W. and A. F. Sievers. A program on the development of domestic tanning materials. *J.A.L.C.A.*, **35**, 647 (1940).

6. Giglioli, G. R. Acacias and other tanniferous plants of South Africa. *Agr. Coloniale* (Italy), **31**, 401 (1937). Through *Chem. Abst.*, **32**, 1510 (1938).

7. Stockberger, W. W. The production of new tanning materials in the United States. *J.A.L.C.A.*, **5**, 35 (1910).